Image from NASA:
https://commons.wikimedia.org/wiki/File:Earth_Western_Hemisphere_transparent_background.png#filelinks

Digital Cartography

Visualizing Data

WV VIEW

AmericaView
Empowering Earth Observation Education
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The goal of this module is to explore some theories and best practices that guide the visualization of variables in graph and map space. My goal here is to provide you with a conceptual framework to guide your data visualization and map design decisions.

Module Topics

1. Grammar of Graphics
2. Data types and levels of measurement
3. Position and map projection
4. Visualizing data using shape, size, color, perspective height, spacing, orientation, or arrangement
5. Types of thematic maps

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These are the topics covered in this module.

Grammar of Graphics

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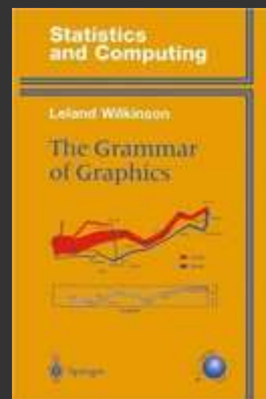
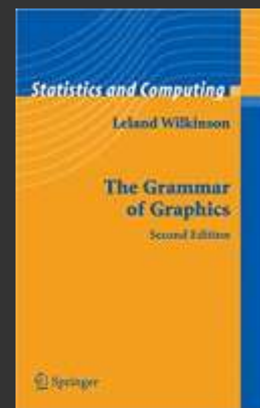
Grammar of Graphics

- Leland Wilkinson
- 1st Edition: 1999
- 2nd Edition: 2005
- Grammar/philosophy for visualizing data
- Map data to graphical parameters (aesthetic mappings)





https://www.springer.com/gp/book/9780387245447

https://towardsdatascience.com/a-comprehensive-guide-to-the-grammar-of-graphics-for-effective-visualization-of-multi-dimensional-1f92b4ed4149b

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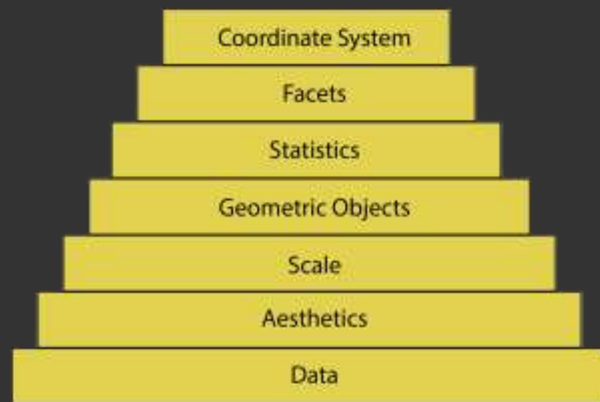
The *Grammar of Graphics* was proposed by Leland Wilkinson and offers a framework, philosophy, and grammar for visualizing data. A central component of this philosophy is the assignment of data to graphical parameters, or defining aesthetic mappings. The *Grammar of Graphics* has greatly informed effective data visualization and is also useful for guiding thematic map design.

Grammar of Graphics

- Coordinate System: What kind of a coordinate system should the visualization be based on?
- Facets: Do we need to create subplots based on specific data dimensions?
- Statistics: Do we need to show some statistical measures in the visualization like measures of central tendency, spread, and/or confidence intervals?
- Geometric objects: This would cover the way we would depict the data points on the visualization. Should they be points, bars, lines, and so on?
- Scale: Do we need to scale the potential values and/or use a specific scale to represent multiple values or a range?
- Aesthetics: Confirm the axes based on the data dimensions, positions of various data points in the plot. Also check if any form of encoding is needed including size, shape, color, and so on which are useful for plotting multiple data dimensions.
- Data: Always start with the data, identify the dimensions you want to visualize.



https://www.springer.com/gp/book/9780387245447

https://towardsdatascience.com/a-comprehensive-guide-to-the-grammar-of-graphics-for-effective-visualization-of-multi-dimensional-1f92b4ed4149b

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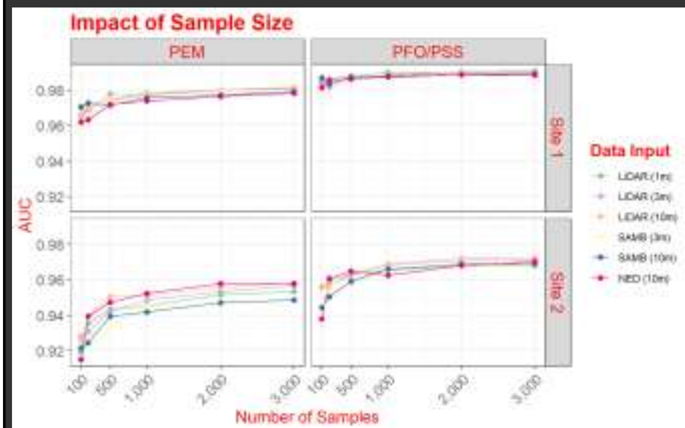
Based on the *Grammar of Graphics*, all graph and map design begins with data. The data scientist or cartographer must decide what dimensions of the dataset should be visualized in the graph or map space.

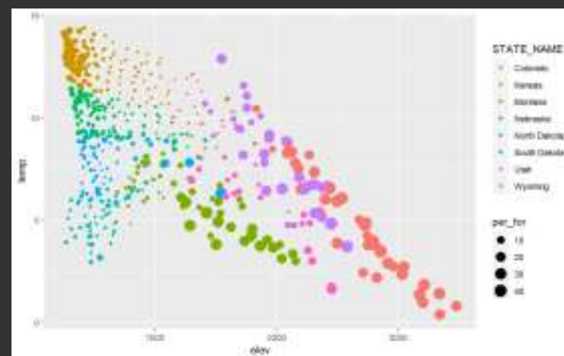
Aesthetic mappings are then used to visualize these data based on their location in the map or graph space or their assignment or visualization with a graphical property, such as color, shape, size, etc. The appropriateness of different graphical parameters for visualizing data depends on the data in question (i.e., nominal, ordinal, interval, or ratio). We will discuss this in the next section.

Next, appropriate scales must be defined. This could include ranges in the x- and y-direction or geographic extent in map space. Appropriate color ramps and binning methods, size ranges, sets of shapes, etc. must also be defined. You must also decide what geometric objects should be used to represent data. Options include points, such as a scatterplot or proportional symbol map, bars, such as bar graphs, or lines, such as time series graphs or flow maps.

We can also include data summarizations and statistics, such as measures of central tendency and/or variability, and confidence intervals. Facets can be used to break the data into multiple plots or maps based on a categorical or grouping variable. Lastly, coordinate systems can be altered. For example, graphs can make use of Cartesian coordinate space or polar coordinates. Maps can be referenced to a globe or projected using appropriate coordinate systems.

Grammar of Graphics





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Let’s explore the *Grammar of Graphics* using some examples.

The graph on the right represents a plot that compares the prediction of wetland occurrence using different terrain surfaces at different resolutions. The position on the x-axis is used to represent training sample size while the position on the y-axis represents the measure of accuracy, in this case the area under the receiver operating characteristic curve measure. Color is used to differentiate the 7 different data inputs. The x- and y-scales are defined to capture the full data range. The data are represented using a combination of point and line symbols. The facets are defined based on two grouping or categorical variables: the study site defines the rows and the wetland type (palustrine emergent vs. palustrine forested/shrub/shrub) defines the columns. Lastly, we make use of a Cartesian coordinate system.

The graph on the left represents climate data for the High Plains states summarized by county. Each data point represents a county. The x-axis position is defined by the mean county elevation, and the y-axis position is defined by the mean annual county temperature. Size is used to represent percent forest cover within the county whereas color represents the state in which the county occurs. Scales must be defined for the x- and y-axis along with ranges of sizes for percent forest cover and colors for each county. The data are symbolized using points with no faceting and within a Cartesian coordinate system.

Data Types

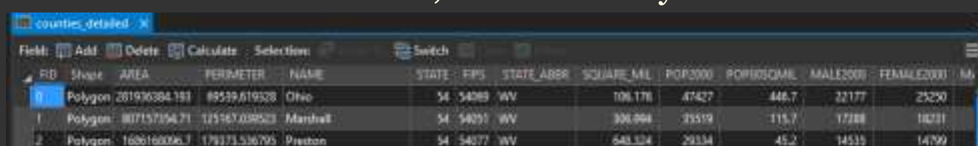
Data Types

Categorical or Qualitative

- Attributes = non-spatial characteristics associated with spatial data
- Nominal = A unique identifier/unique types
- Ordinal = Ranked data

Numeric or Quantitative

- Interval = Difference between numbers is significant, but no fixed, non-arbitrary zero point
- Ratio = Difference between numbers is significant, and there is a fixed, non-arbitrary zero value



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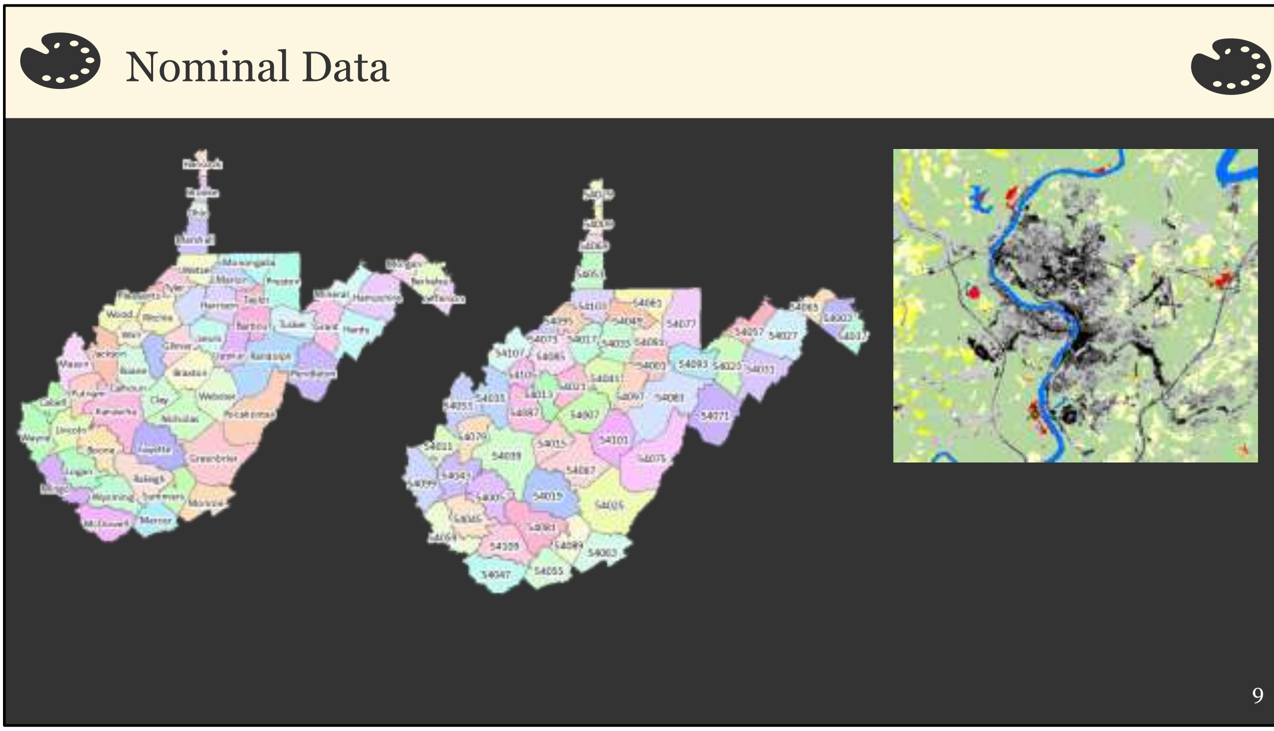
Before we talk about data visualization, we need to talk about types of data, as only certain graphical parameters are appropriate for certain data types. Also, the appropriate use of graphical parameters can change by data type.

Data can be broken into two broad categories: categorical/qualitative and numeric/quantitative. Categorical data represent discrete categories that are either unordered (nominal) or ordered (ordinal). Examples of nominal data include land cover types, soil types, or vegetation types while an example of ordinal data would be rankings such as 3rd place, 2nd place, and 1st place.

Numeric data represent continuous numbers or measures and can be further subdivided into interval and ratio types. For both types the difference between subsequent numbers is fixed; for example, the length difference between 2 meters and 3 meters is the same as the difference between 7 meters and 8 meters. However, they differ in regards to how the zero value is defined. For interval data, the zero value is arbitrary whereas this value is non-arbitrary for ratio data.

Temperature in Fahrenheit or Celsius is an example of interval data as zero temperature on these scales does not mean “no temperature.” Further, ratios cannot be calculated for interval data because, without a fixed zero value, measures that are twice as large do not indicate twice the magnitude. For example, 40° Celsius is not twice as hot as 20° Celsius.

Examples of ratio data include lengths, areas, and percentages since the zero value does have meaning or is non-arbitrary. For example, 0% unemployment indicates that no proportion of the working population is unemployed. 40% unemployment is twice the rate of 20% unemployment.

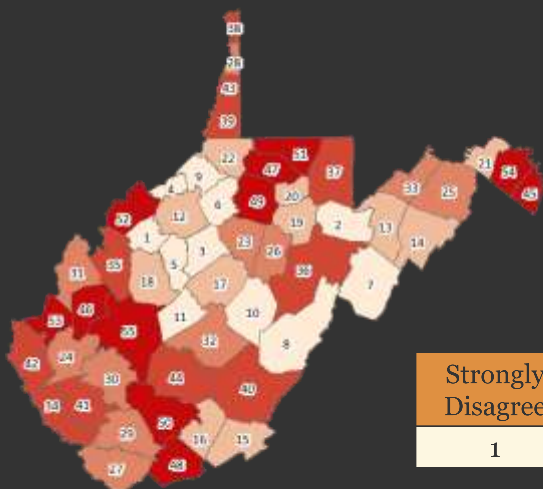


This slide provides some examples of nominal data as county names, county FIPS codes, and land cover categories.

These are all unique categories with no implied order.

Note that it is possible to use numbers to represent categories. For example, FIPS, or Federal Information Processing Standard, codes are numbers. However, in this case they are not being used as numbers. Instead, they are being used to represent a specific feature. Another similar example would be ZIP codes.

Ordinal Data



Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

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Ordinal data represent categories with an applied order, such as ranks.

Survey questions, such as Strongly Disagree to Strongly Agree (Likert scale), are also ordinal data since there is an implied order in the groupings.

Interval Data

Image from the National Weather Service

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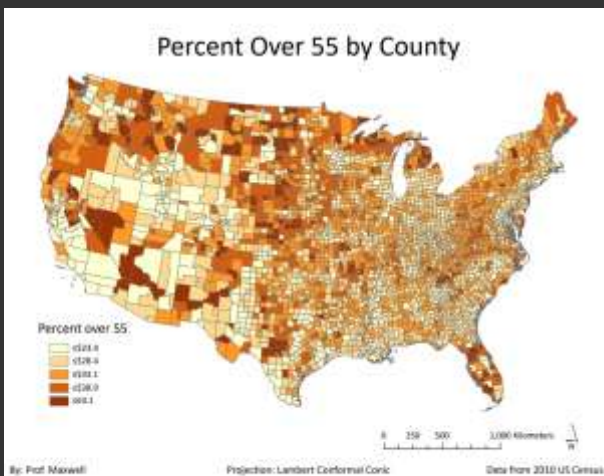
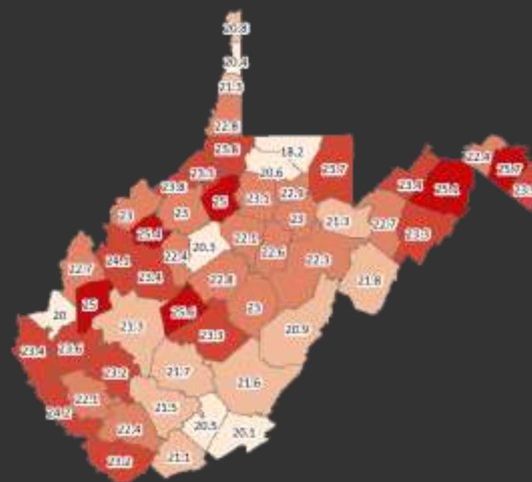
Temperature in Fahrenheit or Celsius and time are examples of interval data.

The zero value is arbitrary and meaningful ratios cannot be calculated.

Ratio Data





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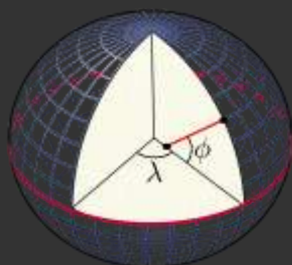
Percentages are examples of ratio data.

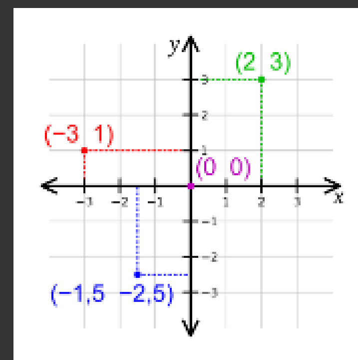
The zero value is non-arbitrary and meaningful ratios can be calculated.

Position and Projection

Position

- Location relative to an origin
- Location in geographic space
- Location in projected map space





https://commons.wikimedia.org/wiki/File:Cartesian_coordinate_system_(comma).svg

https://commons.wikimedia.org/wiki/File:Latitude_and_longitude_graticule_on_an_ellipsoid.svg

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In map space, the position in the x- and y-directions is defined based by the location of the map features. So, these positional graphical parameters cannot be used to visualize data attributes.

If you need a refresher on map datums and projections, please work through the review Datums and Projections module. Here, I want to elaborate on some key considerations.

Types of Map Projections

- ❖Conformal Projections = preserves local angles and shape
- ❖Equivalent Projections = represents areas in correct relative size
- ❖Equidistant Projections = maintains consistent scale along certain lines
- ❖Azimuthal Projections = maintains certain accurate directions

- ❖Conformal and equivalent properties are mutually exclusive
- ❖Conformal and equivalent properties are global properties
- ❖Equidistant and azimuthal properties are local properties and may be true only from or to the center of the map projection

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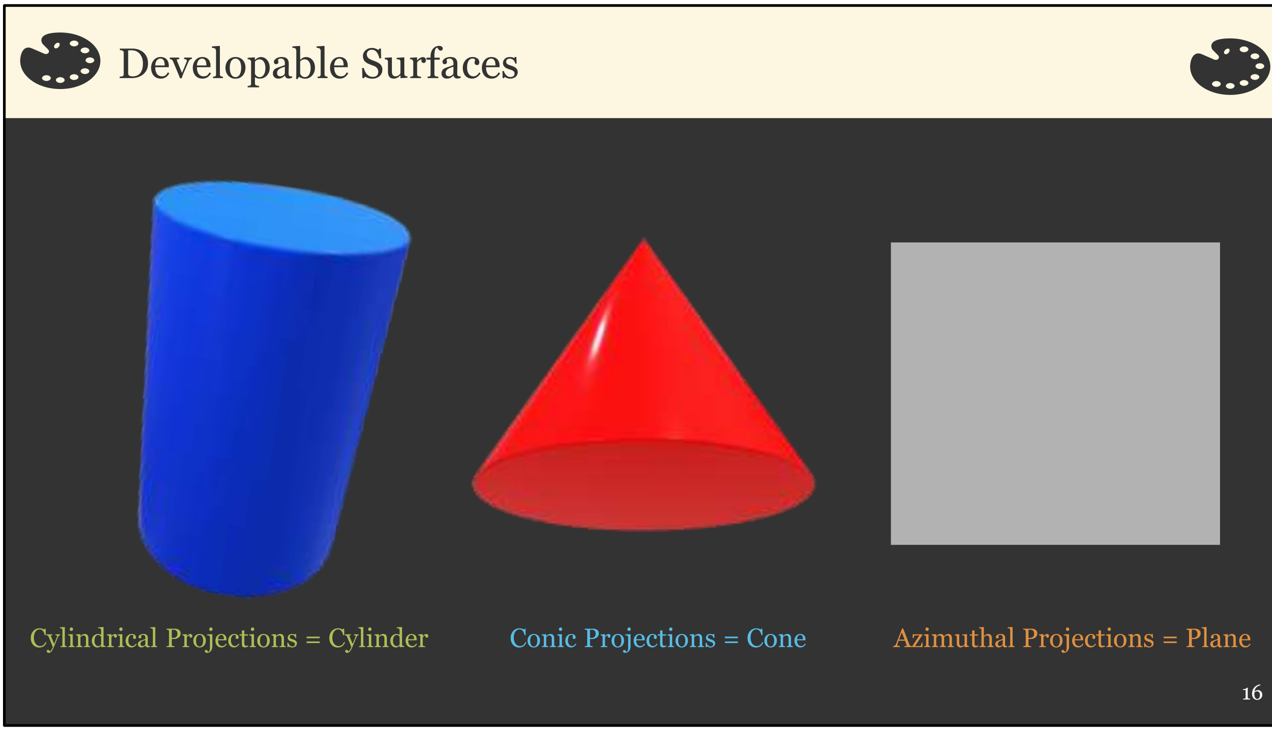
Four broad types of projections exist based on what map properties are maintained.

Conformal projections maintain local angles and shapes. Equivalent projections maintain areas of features in correct relative size. Both are global properties, or shape or size can be maintained across the entire globe or extent, not just for specific areas. Also, these properties are mutually exclusive: you cannot maintain both shape and relative size.

Equidistant projections maintain scale or distance along certain lines while azimuthal projections maintain accurate compass directions relative to a certain vantage point. Equidistant and azimuthal properties are local properties and may be true only from or to the center of the map projection. You cannot maintain distance or direction between all points in the map space.



In order to flatten the Earth, coordinates on the globe must be mathematically transformed or moved to a geometric surface that can be flattened. These are called developable surfaces.

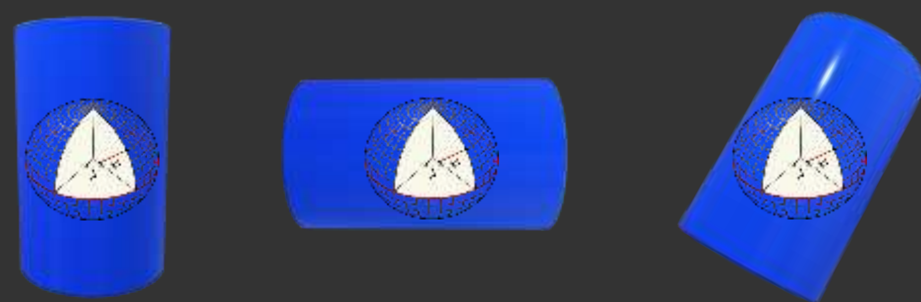
The most commonly used surfaces are cylinders, cones, and planes. Cylindrical projections use cylinders, conic projections use cones, and azimuthal projections use planes.

There are other shapes available, or shapes can be combined. Here, we will focus on just these most commonly used surfaces.

Note that all three of these surfaces can be flattened. If you cut a cylinder, it can be folded out to a plane. A cone can be folded out into a fan shape.

Orientations

❖Planes, cones, and cylinders



Normal　　Transverse　　Oblique

https://commons.wikimedia.org/wiki/File:Latitude_and_longitude_graticule_on_an_ellipsoid.svg

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Orientation relates to how a developable surface is oriented or positioned relative to the globe.

For example, for a cylinder the normal orientation is oriented up-and-down relative to the globe; the long axis is placed perpendicular to the equator.

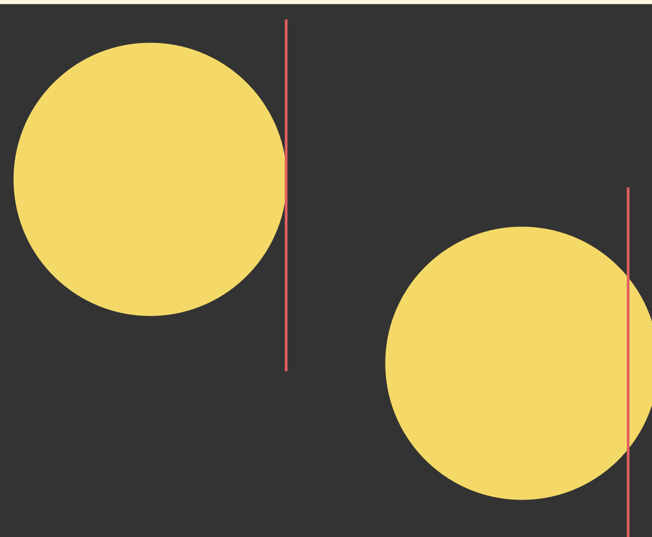
In contrast, the transverse orientation is oriented parallel to the equator.

Oblique orientations are any other orientation other than normal or transverse.

So, given the wide variety of developable surfaces and orientations, the number of possible map projections are infinite.

Tangency and Secancy

- Standard Line = where projection touches the globe
- Standard Parallel = standard line on a parallel
- Standard Meridian = standard line on a meridian



No distortions at these locations

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Projections can also vary in regards to where and how they intersect the surface of the Earth or globe.

Tangency occurs when the developable surface only touches the globe at a single location or along one parallel or meridian while secancy occurs when the surface touches the globe along two latitude or longitude lines.

Standard lines are where the projection touches or spatially co-occurs with the globe. Standard parallels are parallels or latitude lines where the projected surface intersects the globe while standard meridians are meridians or longitude lines.

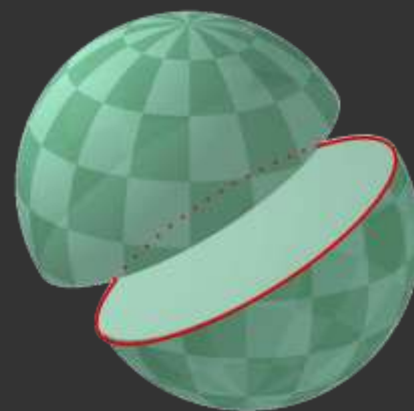
Generally, there are no distortions where the globe and developable surface co-occur, since the coordinates do not need to be transformed or moved.

Distortions tend to increase with distance from the standards.

Again, given the wide variety of developable surfaces, orientations, and standard lines, the number of possible map projections is infinite.

Great Circles

- Distance measured on the ellipsoid and along a plane that passes through the Earth's center
- Shortest path between two points on the globe
- Straight lines in a map projection are generally not straight lines and not the shortest path
- Can be used to approximate distance distortions



https://commons.wikimedia.org/wiki/File:Great_circle_hemispheres.png

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Great circles represent distances measured on the ellipsoid and along a plane that passes through the Earth's center, and they represent the shortest path between two points on the globe.

Any plane that passes between two point on the globe and also the center of the Earth is a great circle. For example, the equator is a great circle since this plane includes the center of the Earth and cuts the Earth into two equal halves.

No other latitude lines are great circles because the planes do not contain the center of the Earth and do not split the Earth into equal-sized halves. All lines of longitude are great circles as they do contain the Earth's center and cut the Earth into equal halves.

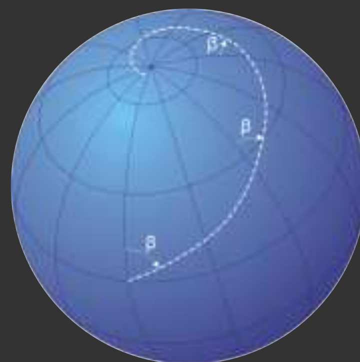
Due to map projection distortions, straight lines on maps are not always great circles and are generally not the shortest path between two points.

Great circle distances are commonly used to approximate the distance between points on the globe and can be used to assess distance distortions.

Planes and ships often do not follow an exact great-circle route, even though a great circle is the shortest path between two points on a sphere, because real-world navigation must account for winds, currents, weather, traffic control, hazards, restricted areas, fuel efficiency, and safety. On a map projection such as Mercator, great-circle routes appear curved, but that does not mean they require constant manual course corrections; modern navigation systems can follow them accurately.

Rhumb Lines

- Rhumb
- Loxodrome
- Arc crossing all meridians of longitude at the same angle
- Path with constant bearing
- Straight line on Mercator projection



https://commons.wikimedia.org/wiki/File:Loxodrome.png

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Although great circles represent the shortest paths between two locations on a globe, using them for navigation can be less convenient because following a great-circle route generally requires a continually changing bearing. Historically, navigators often used rhumb lines, also called rhumbs or loxodromes, because they maintain a constant bearing. Traveling along a rhumb line therefore does not require changing the compass heading, which simplifies navigation. On a Mercator projection, rhumb lines plot as straight lines. Rhumb lines cross all meridians, or longitude lines, at the same angle.

Defining a Projection

- Reference Globe: ellipsoidal model
- Developable Surface (Class)
- Point of Projection
- Point/Line(s) of Tangency or Secancy (Case)
- Aspect: equatorial, oblique, or polar
- Distortion patterns (conformal, equivalent, equidistance, azimuthal, compromise)

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There are a variety of factors that define a map projection. First, different datums, ellipsoids, or models of the globe are available to which a projection can be referenced. Different developable surfaces can be used, and different points of projection can be defined, which act as the point of reference for projecting the coordinates on the globe to coordinates on the developable surface. Where the developable surface will intersect the globe along points/lines of tangency or secancy can be altered. The orientation of the developable surface relative to the globe can be changed. Lastly, what distortions will result and the patterns of these distortions will depend on the type of projection used: conformal, equivalent, equidistance, azimuthal, or compromise.

Projection/Coordinate System Considerations in Map Design

1. Scale/Extent of map
2. Acceptable distortions
3. Unacceptable distortions
4. Use of map
5. Presentation of data
6. Cartographic standards

Different factors should be considered when choosing an appropriate projection or coordinate system for map display. First, you should consider the scale and extent at which the map will be produced. Some projections are appropriate for global extents while others are appropriate for continental, regional, or local scale maps.

You also need to determine what distortions should be avoided and which are acceptable. Do relative sizes need to be maintained or feature shapes? Is direction or distance between certain points important?

You should consider how the map will be used. Will it be used by professionals for data visualization or to communicate to the public? How might the map projection impact the presentation or visualization of the data and information?

Lastly, you should consider cartographic standards appropriate to the map type you are producing and geographic extent to be visualized.

Projection/Coordinate System Considerations in Map Design

1. Choosing a projection can be difficult
2. What projection properties must be preserved, as far as possible, for mapping task, and which are less important?
3. Are the deformational characteristics acceptable, considering where the mapped area lies in relation to the projection?
4. Can the projection be manipulated to improve certain characteristics such as re-centering it?
5. Will the shape of the resulting map be familiar to map readers, or does the pattern of the graticule create an overly awkward appearance?
6. Is the data to be used in the mapping task in a suitable format for projection or reprojection to the chosen map projection?
7. Is the projection supported in the software to be used or will it need to be created?

Field, K., 2018. *Cartography*. Esri Press.

Snyder, J.P., 1987. *Map projections--A working manual* (Vol. 1395). US Government Printing Office.

Bugayevskiy, L.M. and Snyder, J., 1995. *Map projections: A reference manual*. CRC Press.

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This slide highlights some key questions to consider when choosing a map projection and is based on the work of Snyder (1987). Take some time to read through these suggestions.

Global Projections

Named Projection	Property	Characteristic
Mercator	Conformal	Constant scale along equator/straight rhumb lines
Transverse Mercator	Conformal	Constant scale along a meridian
Oblique Mercator	Conformal	Constant scale along an oblique great circle
Mollweide	Equivalent	Noninterrupted
Eckert IV & VI	Equivalent	Noninterrupted
Sinusoidal	Equivalent	Noninterrupted
Goode's Homolosine	Equivalent	Interrupted
Polar Azimuthal Equidistant	Equidistant	Centered on a pole
Oblique Azimuthal Equidistant	Equidistant	Centered on a city
Miller Cylindrical	Compromise	
Robinson Pseudocylindrical	Compromise	

Snyder, J.P., 1987. *Map projections--A working manual* (Vol. 1395). US Government Printing Office.

Bugayevskiy, L.M. and Snyder, J., 1995. *Map projections: A reference manual.* CRC Press.

This table summarizes some projections that may be appropriate for a global scale map. Remember that conformal projections maintain shapes and local angles while equivalent projections maintain relative size. Compromise will distort both shape and relative size with a goal of compromising between the different distortions.

Projections also have certain characteristics that may make them more or less suitable for specific map. For example, the Mercator projection maintains constant scale along straight rhumb lines. The Polar Azimuthal Equidistant projection maintains the correct distance from the North or South pole to all locations on the map. Some projections will maintain continental or ocean basin extents as single, uninterrupted units while others will not.

Hemispheric Projections

Named Projection	Property
Stereographic Conformal	Conformal
Lambert Azimuthal Equivalent	Equivalent
Azimuthal Equidistant	Equidistant
Orthographic	Global Look

North Pole Orthographic (ArcGIS Pro)
*OSM Base Map

Snyder, J.P., 1987. *Map projections--A working manual* (Vol. 1395). US Government Printing Office.

Bugayevskiy, L.M. and Snyder, J., 1995. *Map projections: A reference manual.* CRC Press.

Hemispheric-scale maps generally use stereographic projections if it is desired to maintain shape and Lambert Azimuthal projections if it is desired to maintain relative size. Azimuthal Equidistant projections are commonly used for Polar maps that show just the northern or southern hemisphere. Lastly, orthographic projections can be used to provide a global, spherical rendering of a single hemisphere.

Continent, Ocean, or Smaller Region

Named Projection	Property	Directional Extent	Location
Mercator	Conformal	East-West	Along the Equator
Cylindrical Equivalent	Equivalent	East-West	Along the Equator
Lambert Conformal Conic	Conformal	East-West	Away from the Equator
Albers Equivalent Conic	Equivalent	East-West	Away from the Equator
Transverse Mercator	Conformal	North-South	Aligned anywhere along a meridian
Transverse Cylindrical Equivalent	Equivalent	North-South	Aligned anywhere along a meridian
Oblique Mercator	Conformal	Oblique	Anywhere
Oblique Cylindrical Equivalent	Equivalent	Oblique	Anywhere
Stereographic	Conformal	Equal Extent	Polar, Equatorial, or Oblique
Lambert Azimuthal Equivalent	Equivalent	Equal Extent	Polar, Equatorial, or Oblique

Snyder, J.P., 1987. *Map projections--A working manual* (Vol. 1395). US Government Printing Office.

Bugayevskiy, L.M. and Snyder, J., 1995. *Map projections: A reference manual.* CRC Press.

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Continental to regional scale maps commonly use either Mercator or Lambert Conformal Conic projections to maintain shape and local angles. Mercator projections are specifically useful for navigation due to rhumb lines being represented as straight lines. To maintain relative size, Albert Equivalent Conic Projections are often used. Another consideration is the directional extent of the map, or whether it is oriented east-west, north-south, or oblique.

For more local-scale maps, such as maps of individual states, counties, or cities, it is common to use Transverse Mercator projections, such as UTM Zones. However, this may not be appropriate if a feature cuts across several zones. For example, West Virginia occurs almost completely within UTM Zone 17 North, other than a small section of the eastern panhandle, so it is common to use the 17 N projection for all of West Virginia. In contrast, Pennsylvania is split between UTM Zone 17N and 16N, so neither would be appropriate for the entire state. Instead, a Lambert Conformal Conic or Albers Equivalent Conic projection would be more appropriate.

For very large-scale maps, such as maps of individual cities, a UTM projection or a State Plane projection is commonly used.

PROJ

- Formerly PROJ.4
- Open-source software/library for performing conversions between cartographic projections/coordinate systems
- Standard syntax for defining projections and coordinate systems
- Most open-source geospatial software rely on PROJ

NAD83 UTM Zone 17N

+proj=utm +zone=17 +ellps=GRS80 +datum=NAD83 +units=m +no_defs

US Contiguous Albers Equal Area Conic

+proj=aea +lat_1=29.5 +lat_2=45.5 +lat_0=37.5 +lon_0=-96 +x_0=0 +y_0=0 +ellps=GRS80 +datum=NAD83 +units=m +no_defs

https://proj.org/

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PROJ (formerly PROJ.4) is used in many open-source and commercial software libraries.

It supports standards for defining geographic and projected coordinate systems and converting between specific systems.

PROJ strings offer a common text syntax for describing coordinate systems and their components, such as projection systems, datums, ellipsoids, origins, false eastings and northings, standard parallels and/or meridians, and units of measurement.

Example PROJ strings for the NAD83 UTM Zone 17 North and US Contiguous Albers Equal Area Conic projections are provide on the slide.

EPSG

- Provides a numeric code that references a coordinate system/projection
- European Petroleum Survey Group

NAD83 UTM Zone 17N

EPSG:26917

WGS84 Web Mercator

EPSG:3857

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The European Petroleum Survey Group (EPSG) maintains a reference of geographic and projected coordinate systems.

Along with a PROJ string, coordinate systems are also assigned a unique EPSG code.

Search for Projections/Coordinate Systems

http://spatialreference.org/

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This slide provides a link to the Spatial Reference webpage, which is a standard resource for looking up and referencing different coordinate systems.

Visualizing Data

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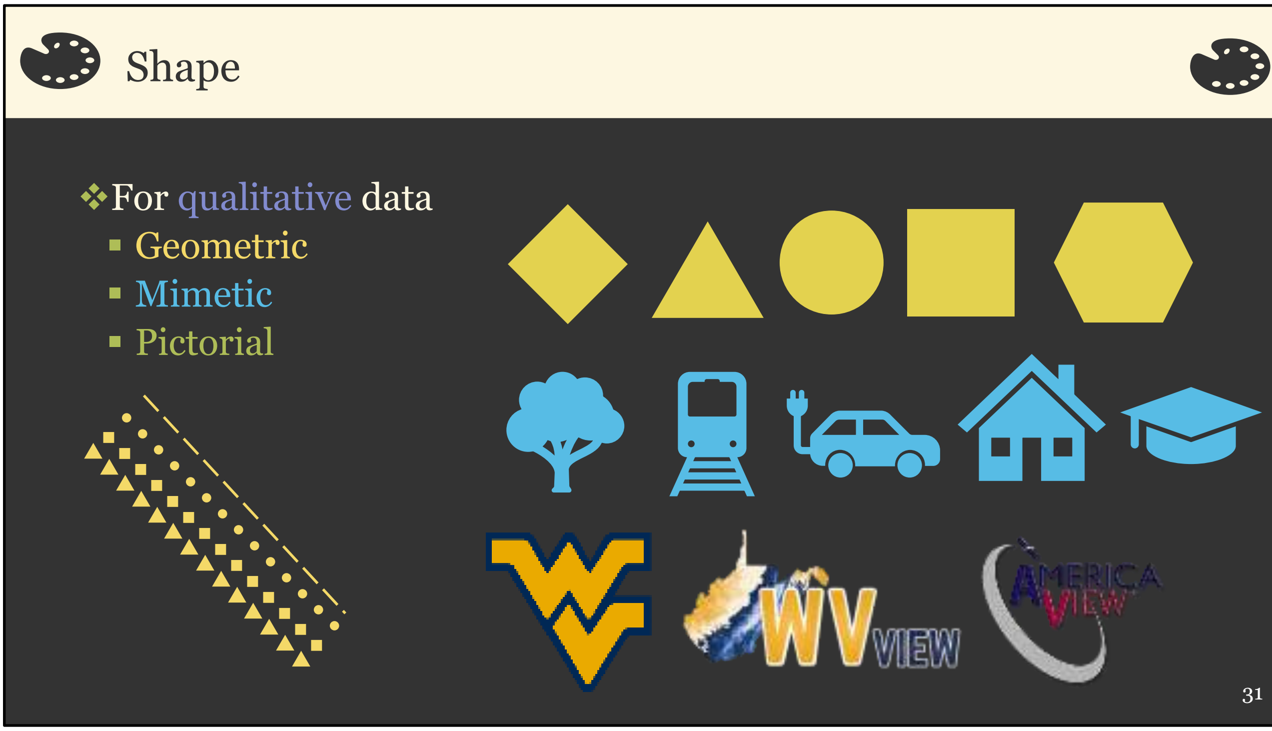
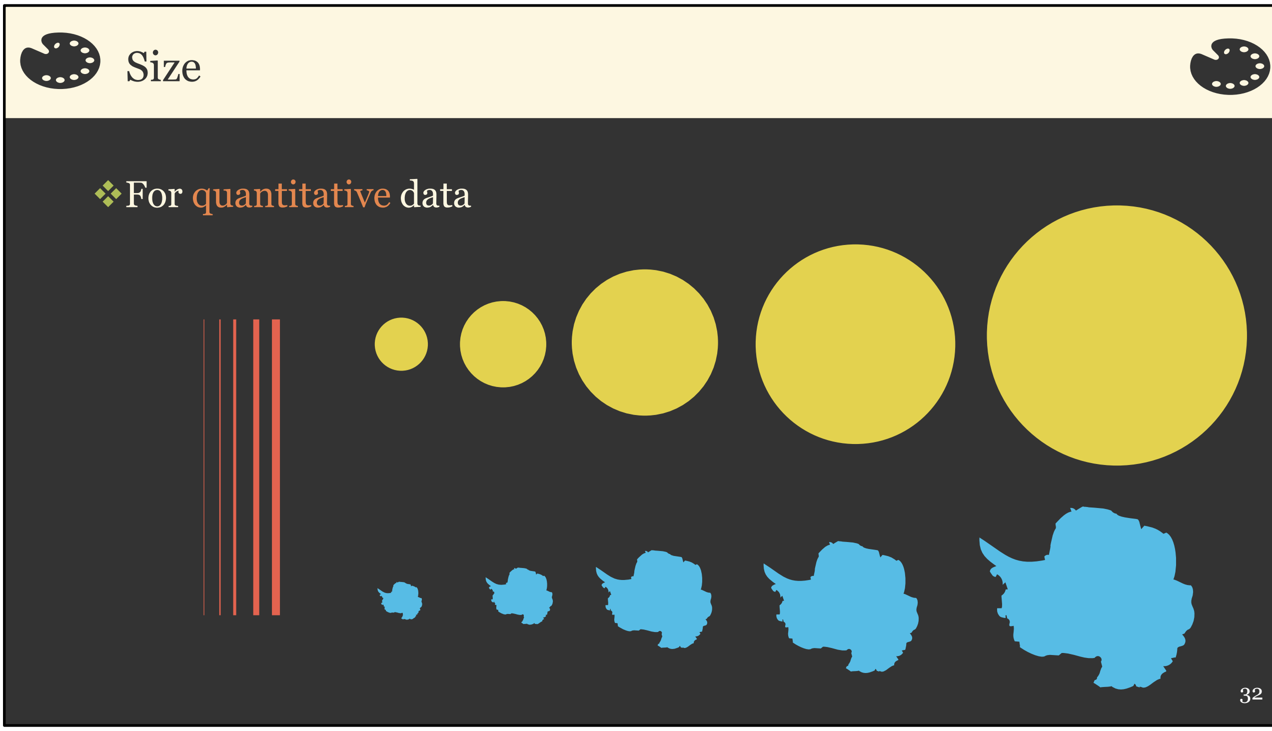


We will now discuss how different graphical parameters can be used to correctly display data. We will begin with shape.

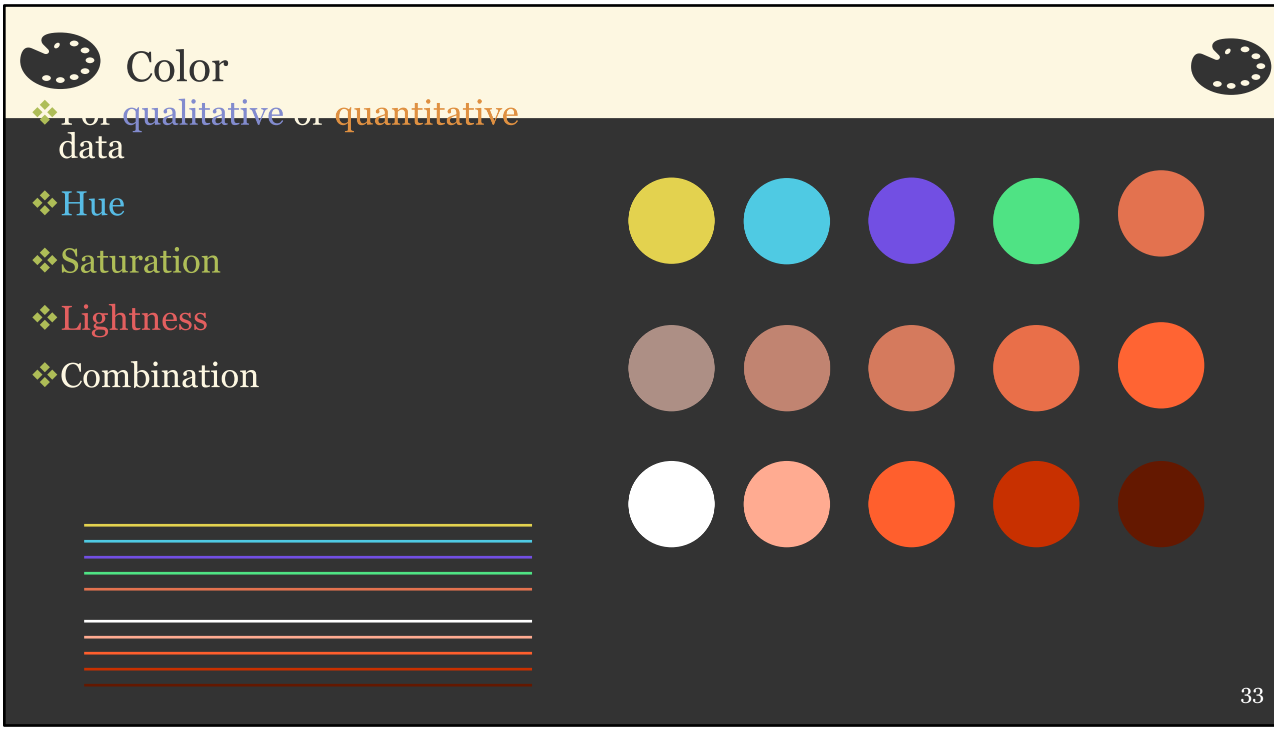
Shape is only appropriate for categorial or qualitative variables since there is no implied increasing or decreasing order. For example, how could you represent crime rates for cities using shape? This really wouldn’t make sense.

Different types of shape-based symbols can be used. Geometric relies on common, generally simple geometric shapes, such as circles, squares, rectangles, ovals, diamonds, stars, and hexagons. Mimetic symbols mimic the feature they are representing, such as the examples provide on the slide. Lastly, pictorial symbols use pictures, such as company logos.

It is also possible to categorize line features with shapes using repeating geometric shapes along the line segments.



Size should only be used to represent numeric data since there is an implied order or sequence from small to large. Larger sizes will indicate larger quantities while smaller sizes will indicate smaller quantities. For lines, the line width or thickness equates to size and again is only appropriate for numeric data. Examples of maps that use size include proportional symbol, graduated symbol, and cartograms.

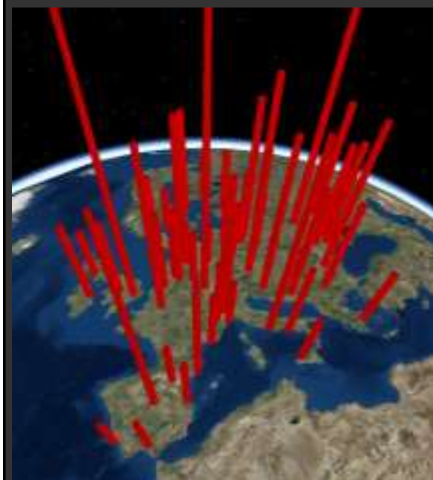


Different aspects of color can be used to represent different types of data.

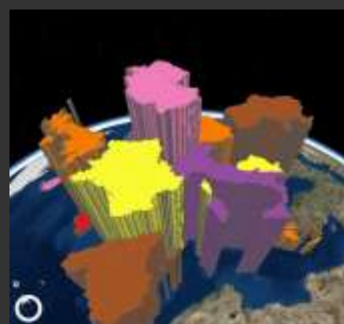
For example, unordered colors that change by hue (or change by base color) can be used to represent categorical or qualitative data, as long as no order is implied by the color choices. The top set of circles and top set of lines are examples.

To use color to represent a quantity, an order should be implied. This generally involves increasing the saturation and/or lightness of a base hue, as demonstrated by the middle-set of circles (where saturation is varied) and the bottom set of circles and lines (where lightness is varied).

Perspective Height



❖For quantitative data



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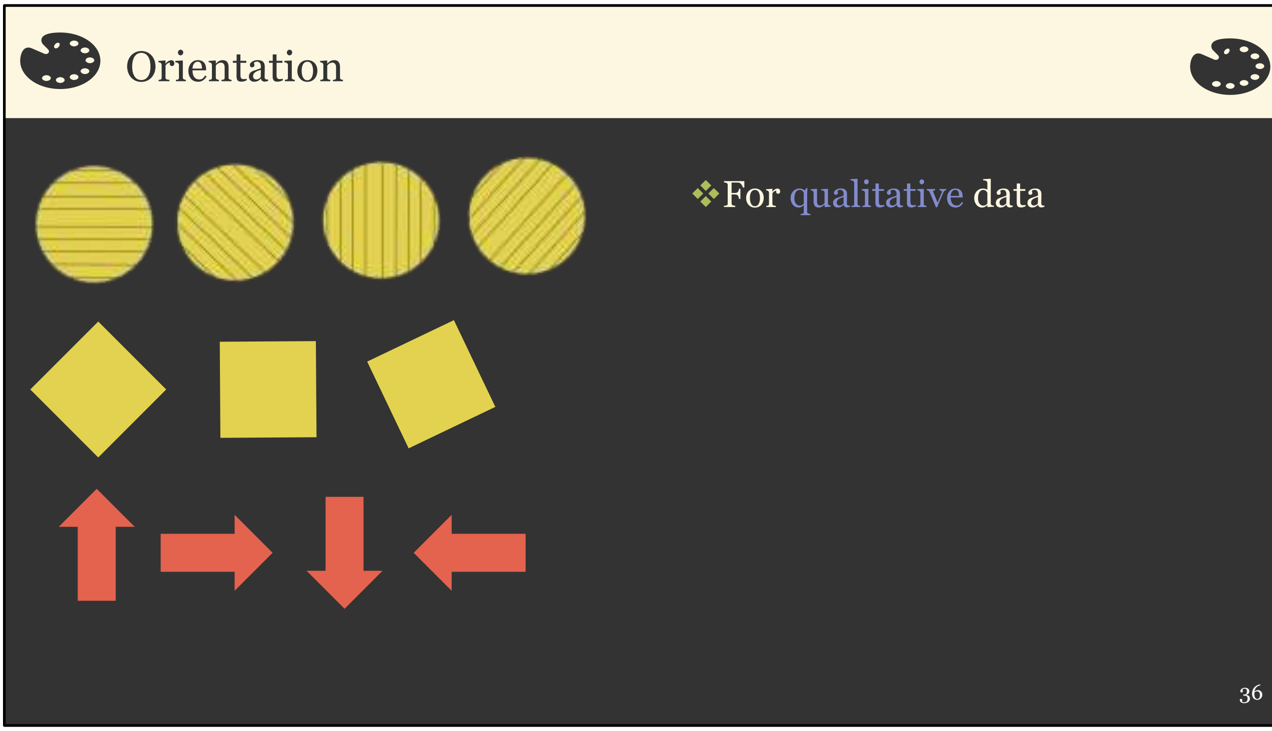
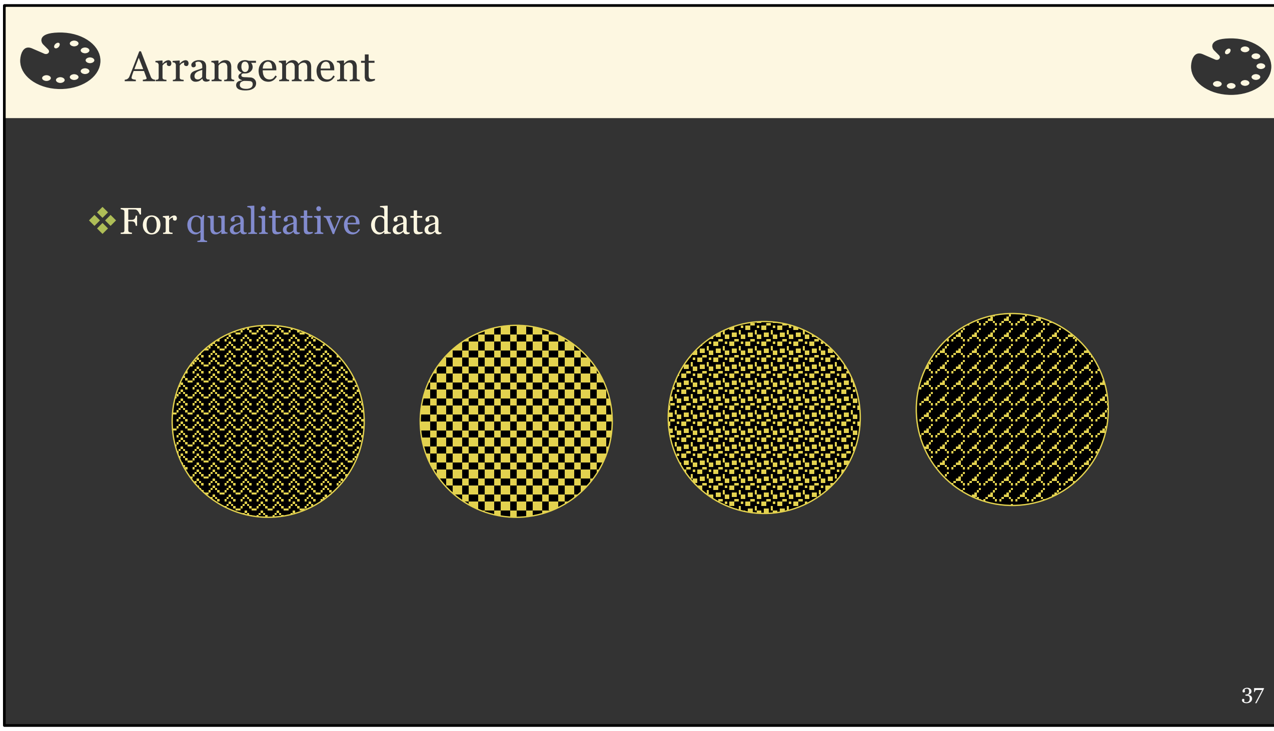
Perspective height can be used in a 3D scene to represent a quantity. Specifically, the height of the feature will be scaled relative to a numeric variable. The examples on the slide relate to population by country and by city and use perspective heights for areal features and points.

It is also possible to combine other graphical parameters. For example, color is used in the country-level map to represent different unordered categories.

Spacing can be used to represent a quantity or numeric variable, but it is not appropriate for categorial data since there is an implied ordering. Generally, denser spacing indicates a larger quantity whereas less dense spacing represents a smaller quantity. For lines, the spacing is represented by the length and spacing between dashes. Areal features can be filled with a pattern that varies only by density.



Orientation can be used to represent qualitative or categorical data but is inappropriate for numeric data, since there is no implied order. To use orientation the same symbol is used to represent a point or fill an areal feature, with only the orientation of the pattern changed.



Another option is to use arrangement to represent categories. In this case, different base patterns with no implied ordering are used to represent different categories.

Comparisons

Graphical Parameter	Nominal	Ordinal	Numeric
Shape	Good	Poor	Poor
Size	Poor	Marginal	Marginal
Hue	Good	Good[1]	Marginal[4]
Saturation	Poor	Marginal	Marginal
Lightness	Poor	Good	Marginal
Perspective Height	Poor	Marginal[2]	Good[5]
Spacing	Poor	Marginal[3]	Marginal[6]
Orientation	Good	Poor	Poor
Arrangement	Good	Poor	Poor

- 1 = with correctly ordered hues
- 2 = use with caution
- 3 = not aesthetically pleasing
- 4 = with correctly ordered hues
- 5 = hidden enumeration units and lack of a north orientation are problems
- 6 = not aesthetically pleasing

Modified from Slocum et al. Figure 5.3

38

This table was modified from the Slocum et al. text and summarizes what graphical parameters are appropriate or best to use for different types of data. Note that numeric includes both interval and ratio data.

Shape is only appropriate for nominal data since there is not implied ordering. Size, since there is implied ordering is not appropriate for nominal data but can be used for ordinal or numeric data, since an implied ordering is desired.

Hue works well for categories and can be used for ordinal data if hues are selected to represent some implied ordering. Generally, altering only the hue is avoided for representing numeric data. However, we will discuss this in more detail in a later module. The color saturation and/or lightness can be used for ordinal and numeric data but are inappropriate for nominal data because an ordering is implied.

Perspective height and spacing can be used for ordinal and numeric data while orientation and arrangement are only applicable to nominal data.

Take some time to study this chart and make sure you understand these recommendations. Also, read through the provided notes pertaining to specific use cases.

Thematic Mapping

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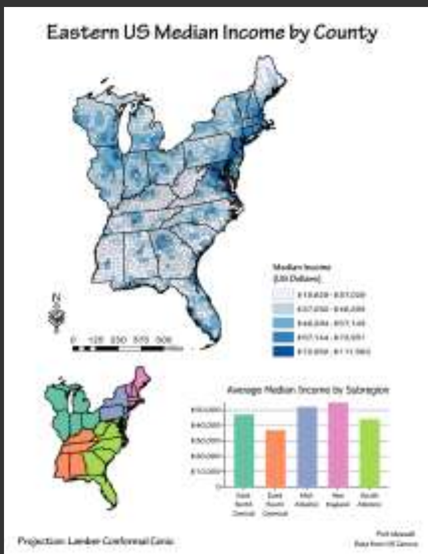
Choropleth



❖ Use color to show a quantity or category

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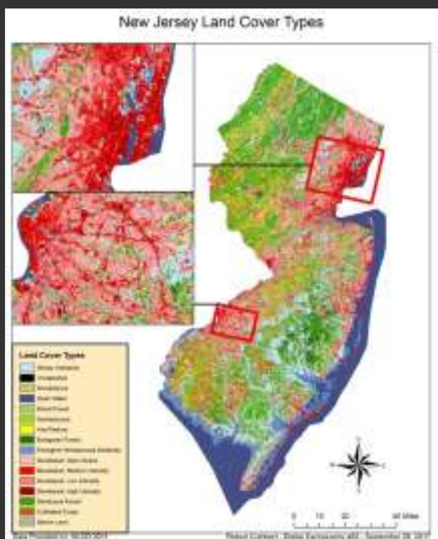
Choropleth maps use color to represent a category or quantity.

In the example provided, shades of blue are being used to represent a quantity, in this case medium income by county.

Also, colors are being used to represent categories, in this case different regions of the eastern United States.

Choropleth



- Use color to show a quantity or category

Map by Robert Cuthbert

41

This is an example of a choropleth map showing categories. Different land cover types are symbolized using unordered colors.

Choropleth

- Use color to show a quantity or category

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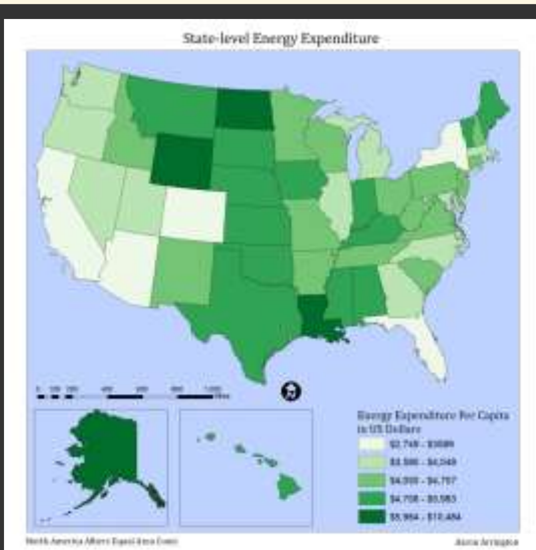
This is another example of a thematic map representing categories.

The two different colors show whether a country was visited or not during a hypothetical trip.

Choropleth



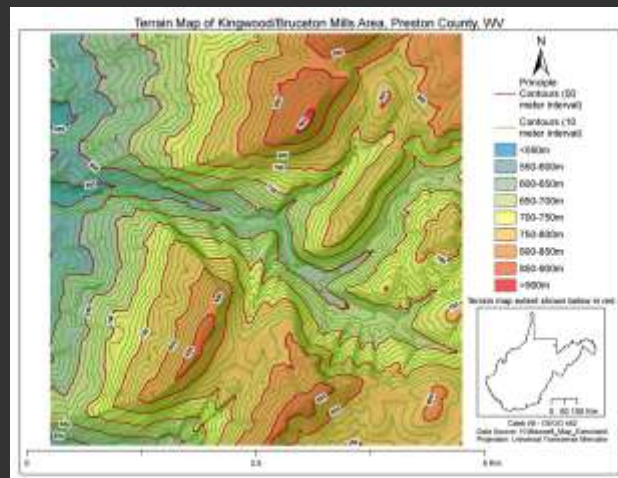
- Use color to show a quantity or category

Map by Aaron Arrington

This choropleth map is showing a quantity as opposed to a category, in this case energy expenditure per capita in US dollars.

Isopleth

- Use lines of equal value to show a quantity



Map by Caleb Alt

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Isopleth or Isarithmic maps use isolines, or lines of equal value, to represent quantities.

They cannot be used to represent categories.

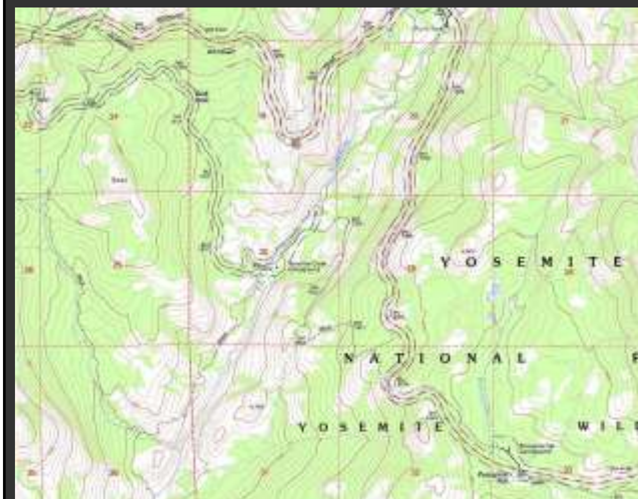
Here, isolines are being used to represent elevation.

If you would walk one of these lines, you would not go up or down hill or change elevation.

Isolines can also be used to represent other continuous phenomenon, such as temperature, barometric pressure, relative humidity, or depth to bedrock.

This map is technically a combination of an isopleth map and a choropleth map as both color and isolines are being used to show elevation.

Isopleth



https://commons.wikimedia.org/wiki/File:Yosemite-creek-campground-topo.jpg

- Use lines of equal value to show a quantity
- Topographic Maps

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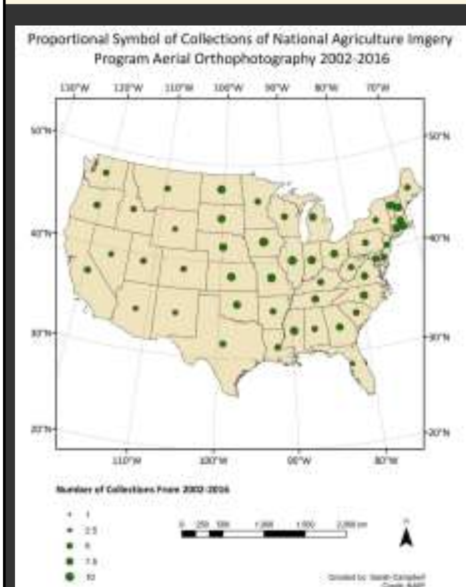
Topographic maps are another example of isopleth maps since contour lines are used to show elevation.

I consider topographic maps to be a combined reference and thematic map since they are commonly used for navigation but also represent topography as a theme.

Proportional Symbol



- Use size to represent a quantity (scaled continuously)

Map by Sarah Campbell

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In contrast to choropleth maps, proportional symbol maps use size as opposed to color to show a quantity. Proportional symbol maps cannot be used for categories.

For proportional symbol maps, the size of the symbol is scaled continuously relative to a quantity.

The example above represents the number of aerial image collections by state.

Graduated Symbol

❖ Use size as bins or ranges to represent a quantity

Map by Sarah Campbell

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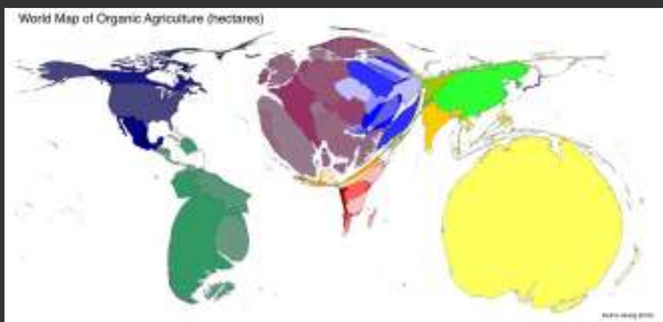
Graduated symbol maps are often confused with proportional symbol maps.

In graduated symbol maps, instead of scaling the sizes continuously, a single size will represent a range of measurements: data are classified or binned.

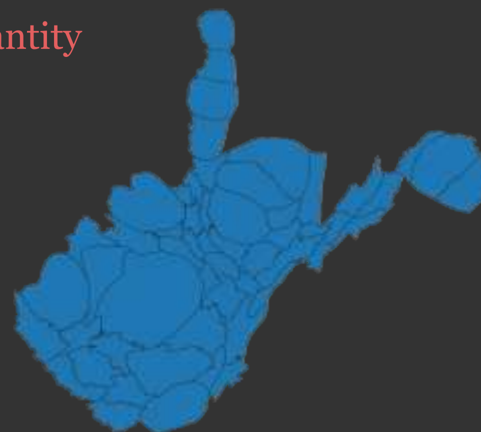
As with proportional symbol maps, these maps are generally only used for quantities and are not appropriate for categories.

Cartograms

❖Resize the map feature to represent a quantity



Paull, J., Hennig, B. (2016) "Atlas of organics: four maps of the world of organic agriculture." *Journal of Organics*, 3(1): 25-32.



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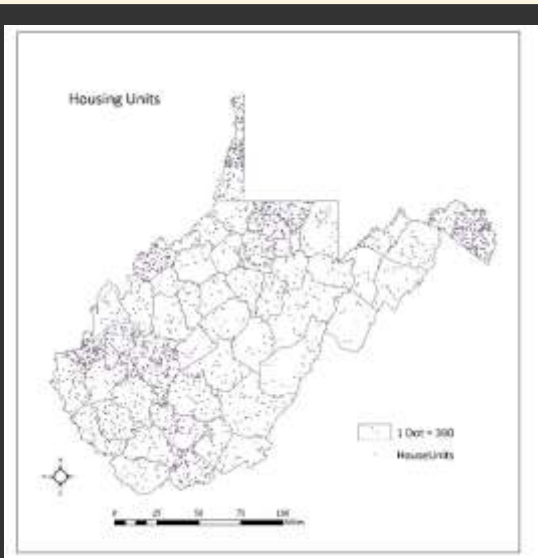
Another way to represent a quantity using size is to make use of cartograms.

Instead of scaling a symbol relative to a quantity, the relative size of the actual geographic feature is scaled relative to a quantity.

So, the size of the map features are distorted to represent a quantity as opposed to changing the size of a symbol.

Dot Density



- Use density of dots to represent a quantity

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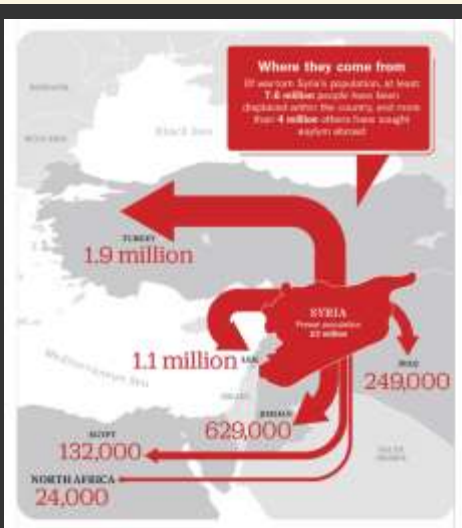
Dot density maps represent a quantity using the density of dots. They are not used to represent categories.

In the provided example, number of houses per county is symbolized using dot density. More dots in a county represent more houses.

Each dot will represent a certain number of features. In the example, each dot represents 390 homes.

It is important to note that the location of the dots do not correspond to the true location of homes. Instead, the dots are randomly placed in the polygons and the number or density of dots per polygon represents the quantity.

Flow Maps



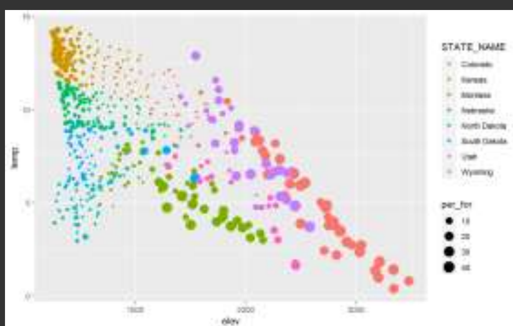
http://time.com/4028055/syria-europe-refugees-graphic/

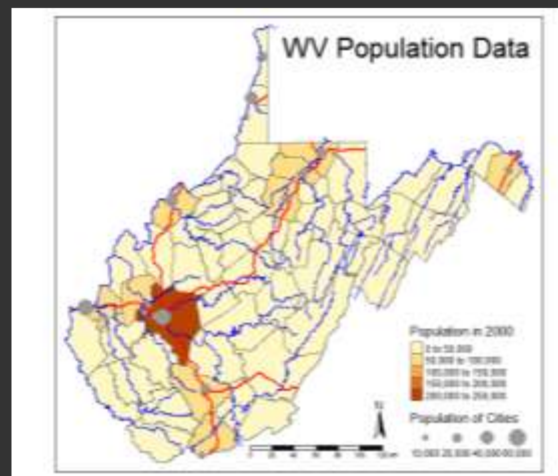
- Show movement or migration using arrows
- Can also show magnitude with arrow size or color
- Can show a qualitative variable with color

Flow maps are used to show movement or migration. In the example, the arrows are being used to show the direction of migration of war refugees while the size of the arrow shows the magnitude or number of refugees. A categorical variable could be shown by using unordered colors applied to the arrows.

Multivariate Maps

- Maps that show multiple quantities and/or categories using different graphical parameters





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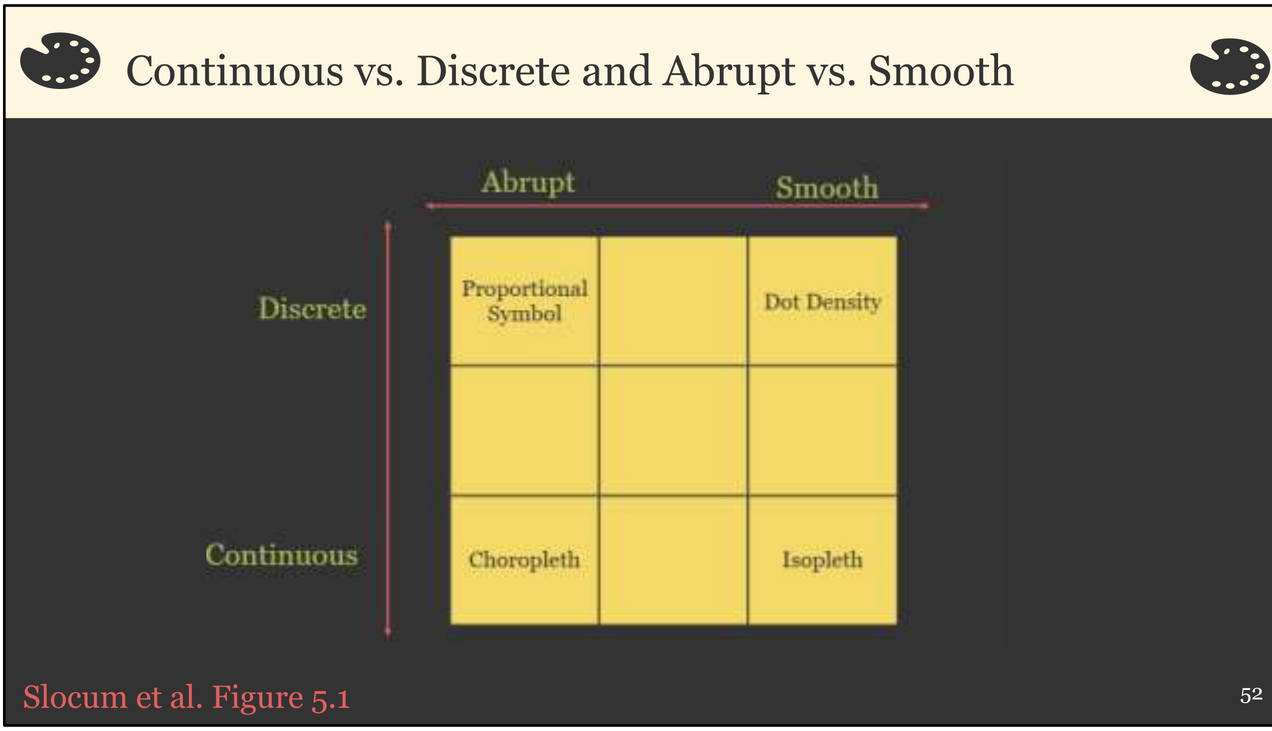
Multivariate maps show more than one theme using different graphical parameters.

For example, the map on the right side is being used to show city populations while color is being used to show county populations.



Deciding on what type of map is best to represent different variables partially depends on the type of data being mapped; however, the choice is also informed by the spatial patterns of the phenomenon.

For example, a variable that occurs at discrete locations on the landscape vs. one that occurs continuously (i.e., there is a value everywhere, like depth to bedrock or elevation) should not be visualized the same. For example, a proportional symbol map or dot density map is more appropriate for discrete data while a choropleth map or isopleth is more appropriate for continuous data. As another example, when representing data at a county-level, the number of employees at a single county high school would be discrete (this is because the data is for a discrete location within the county: the location of the high school), the number of employees at all schools in the county would be intermediate (this is because there are discrete measurements at multiple locations across the county), and the percent of the county population that is school-age would be continuous (this is because this value represents the entire county and there would be a value assigned to all counties and all locations).

You should also consider if the phenomenon can change abruptly vs. smoothly. Proportional symbol maps and choropleth maps are more appropriate when values can change abruptly whereas dot density and isopleth maps are more appropriate for smoothly changing phenomenon. For example, high school graduation rate could change abruptly between adjacent counties; however, average temperature would likely change more smoothly.

This is the end of this lecture module.

Please return to the West Virginia View Webpage for additional content.

Thanks! Hope you found this useful.